4.6 On Not Putting the Cart before the Horse: Design Enables the Prediction of Decisions about Movement in Buildings

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Our principle obstacle to predicting building movement is not movement, it is our ability to predict human decision making about when, where and how to move during building emergencies. However, we will be unable to predict decision making as long as we fail to engineer systems that provide the information that building occupants need to make adaptive decisions. We need to get on with the business of learning how to design these systems that provide an informational cognitive task environment without first waiting for the creation of validated predictive models.

In my view, we are in good shape as regards the optimized *physical* movement of people. This is not to say that models of physical movement can't be improved. There is an acute need to acquire better data to refine and validate these models. However, we are in poor shape as regards modeling the decision-making processes that determine when people start to move, and how they decide by what means that will try to reach what safe destination. I would like to address the issue of how we might go about designing for and modeling decision making.

First and foremost, we are putting the cart before the horse when we try to predict decisions as a means to drive the design of buildings. Simply put, the converse is more accurate—design enables prediction. Without better design1, there it too much uncertainty about the information available to building occupants. Without reasonably detailed data about the information received by building occupants during emergencies, it will be impossible to predict decisions at a useful level of precision.

(Most accurately, the relationship between design and prediction is iterative. Design enables prediction, but prediction enables better design. To the extent that design is improved, earlier predictions are invalidated. However, at this formative stage, we need to start the process with design before we can predict behaviors at a level of validity that allows confidence in new designs based on those predictions.)

An analogy between predicting human decisions and predicting fire development is useful (Groner, 1996). Information about context is essential to both endeavors. Fire protection engineers are unable to predict fire growth and spread without information about fuel loads, room geometry and ventilation. Similarly, we can't predict human decision making without data that describes the informational context encountered by building occupants. Just as contextual information is large determined by design (e.g., knowledge of geometries, existence of suppression systems, restrictions on fuel loads), design is needed to provide the informational context of decision making before it can be predicted at an acceptable level of validity.

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1 By design, I mean to include hardware-enabled, electronic and human procedural systems components.

A large body of theory and practice exists that concerns how to engineer systems that support human decision making. The discipline of human factors engineering is increasingly concerned with discovering and validating approaches that provide people with an engineered context that supports reliable and effective adaptations to dynamic and uncertain environments. These approaches can be generally subsumed under the labels of "cognitive engineering" and "cognitive ergonomics design." These terms have been nicely defined as follows: "Cognitive Ergonomics, a term synonymous with Cognitive Engineering, concerns the design, structure & operation of the interface between the human end-user (operator) of a system and system states and processes. This approach assumes that the way people see, hear, pay attention, think, remember (and forget), and make decisions has direct implications for the design of the artifacts and environments that they use. If the features of their physical surroundings reflect and support their natural cognitive tendencies, then at least users should make less errors when using such systems; at most, their performance and productivity could receive a positive boost."2

Engineers who design the informational environments need to be provided with cognitive task analytical tools that will "yield information about the knowledge, thought processes, and goal structures that underlie observable task performance (Chipman, Shraagen, & Shalin, 2000, p. 3)." We need to survey the human factors literature to find theories and methods that seem promising when applied to human decision making during building emergencies. Hopefully, we will find methods that can be adapted to our domain of interest. At the very least, we are likely to discover valuable insights that will guide our own efforts to support the informational needs of decision makers during building emergencies.

Unfortunately, the large body of cognitive engineering research is not easily transferred to our domain of interest—decision making during building emergencies. Major obstacles must be overcome, because most of this cognitive engineering work concerns domains that differ in important ways from the contexts that people face during fires. As one example, aviation cockpits are exceedingly well-researched domains where operators are trained to a level of expertise using a well-articulated interface to control tightly coupled systems. The following are a few ways in which the building emergency domain differs from those in which human factors professionals are typically concerned.

- Building protective systems are loosely coupled, that is, there is a large amount of uncertainty linking causes to effects. Most cognitive task design methods are applied in domains characterized by tightly coupled systems where operators can effectively control outcomes using a reliable clearly articulated interface.

- People responding to building emergencies typically lack expertise because emergencies are rare chaotic events and extensive training resources are unavailable. Much of the cognitive task design literature concerns domains where people can be trained to achieve some level of proficiency.

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2 (http://connect.haworth.com/txmas/White_Papers/CognitiveErgonomicsDef.doc)

(There are exceptions. The use of elevators to evacuate building occupants is an example. In this instance, it might be feasible train operators to some level of proficiency in controlling a tightly coupled system using an engineered interface.)

First and foremost, we should get on with the business of analyzing and designing cognitive task environments that provide building occupants with accurate and timely information that support their goals of survival and protection. We should not wait until we have methods that predict and model human decision making during building emergencies. Building valid decision models is an important task, but its pursuit is of limited value until we have designed cognitive task environments that enable an acceptable level of predictive validity

To be clear, I strongly support research that studies actual events, but it is premature to accrue *predictive* data for use in decision models. The better reason for studying incidents is to reveal the naturally occurring information processing and goals that occur during incidents. Cognitive task designs need to be compatible with people's natural inclinations, more so in this domain than others. Hands-on experiential training in real emergencies is rare, and training resources are always limited, even for persons selected as emergency team members' roles like floor wardens, so trying to supplant their natural inclinations seems unlikely to be effective. As an example, we have been largely unsuccessful in educating people to immediately evacuate when they hear a simple alarm signal, principally because simple signals provide little useful information about situations, and because people are naturally inclined to assess situations before taking protective actions.

As a final thought, we should keep in mind that predicting human responses is not the goal of design. If we design environments based on the sole criterion of predicting human responses, that is, to maximize human reliability, then we run the risk of interfering with human adaptive abilities. We could conceivably design a system whereby we could constrain decision making such that we could accurately predict which egress routes building occupants choose, but this is not a good idea in itself. We want design environments that enable people to choose the most effective route in response to the chaotic and dynamic environments they face, even at the loss of the predictive validity of our calculations.

References

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5 Workshop Summary

Participants at the workshop representing varied disciplines – psychology, human factors, sociology, engineering, computer science, government agencies, and toxicology – discussed common efforts towards more accurate prediction methods and information on human behavior in fires and other emergencies. There is a great deal of work already completed in many disciplines (information flow, building technology sensors, elevator use, community evacuation planning, group dynamics, etc.) that can be used to provide better prediction tools.

5.1 Overall

Participants of the workshop were introduced to research in many different disciplines with common links between their research and what is going on in the fire field. The collaboration of the disciplines can provide guidance on the several aspects of evacuation:

- How to design buildings for more effective evacuation (building sensors, user-centered integrated model, risk factors).
- How to train occupants for different types of emergencies (emergency planning guidance).
- How to incorporate data/knowledge into current evacuation models (current models are lacking realistic behaviors such as group movement, information on assumption and model limitations are not provided to users).

Several research needs were expressed during the workshop. These include:

- Real-time data of occupant evacuation from buildings (movement and behavioral data such as flows on stairs, speeds, pre-evacuation decisions and times, etc.),
- A method of data/information sharing among researchers and model developers,
- Appropriate design or code changes which reflect the risk of the specific building, instead of reactionary changes,
- A central repository for this type of data in one central place available to the public, and
- Accurate guidance on development of emergency plans for different types of emergencies.

5.2 Specific Needs Obtained From Workshop Participants

There is a need to understand how the people, the building, and the environment react together. This involves an integrated "model" and more of a systems view of the evacuation. Suggestions were made to use technology in buildings (sensors) to help people during their evacuation. For instance, giving them specific information on which route to take or providing them with a sensor at each door to let them know if there is fire or smoke behind the door.

There is a need to better understand the behavioral aspect of evacuation for better prediction methods and more effective training techniques. However, it is not clear how specific this understanding should be to accurately provide safety for building occupants. For instance, do we need to outline each decision made by every occupant during the pre-evacuation stage or is it enough to simply assign a distribution of pre-evacuation time delays to represent time spent before beginning movement toward an exit? In either case, data are needed.

There is a need to collaborate with other disciplines on providing more effective emergency planning. On one hand, we need to know what to expect from occupants and base the emergency plan on that. For instance, people tend to leave the way they come into a building. Because of this, we could possibly widen main doors and/or plan for elevator use in certain emergencies. On the other hand, behavior is pliable and we need to impact occupant behavior in our building design and the information given to occupants. Emergency plans should involve input from the actual occupants and involve extensive practice (even including motivational rewards).

There is a need to include the impacts of human behavior in predictive models. Currently used evacuation models lack certain behavioral aspects of an evacuation, including group behavior and accurate representation of the disabled population. Projects are in the works to help identify gaps in the evacuation models and eventually update current models with needed data. NIST is working to provide a central repository for such data on human behavior and movement during evacuation to make data widely available to researchers. The key is to ensure that available data are sufficiently documented to make it useful to researchers who were not involved in the original data collection or those in disciplines different from the original researchers.

There is a need for building codes and regulations to better reflect the impact of human behavior during emergencies. Much work is needed in the code area to make sufficient changes to current codes in response to recent events. Workshop participants expressed a desire that codes and standards be based on appropriate scientific study rather than reaction to specific events. This would include study not only of changes to specific code requirements but also the overall scope and the balance of cost with benefits provided by major revisions to existing codes and standards.